vibrated, not during, but after, the changes of load through which the given state has been reached.

It is also shown that this approximate equality produced by vibration continues after the vibration ceases. Also, that when a cycle of loads is gone through afterwards, without vibration, the old difference between the "on" and "off" curves reasserts itself.

It is suggested that the cyclic phenomenon so conspicuous in this investigation is not peculiar to the thermoelectric effects of stress, but is probably present in other effects of stress, and may perhaps be found to occur in the changes of any quality of matter which is a function of another variable quality (such as temperature) when the latter quality is subjected to increment and decrement.

Lastly the results of certain independent experiments made by others in other branches of physics are referred to in confirmation of this suggestion.

XII. "On the Reversal of the Lines of Metallic Vapours. No. VIII. (Iron, Titanium, Chromium, and Aluminium.)" By G. D. Liveing, M.A., F.R.S., Professor of Chemistry, and J. Dewar, M.A., F.R.S., Jacksonian Professor, University of Cambridge. Received June 2, 1881.

In our last communication on this subject we observed ("Proc. Roy. Soc.," vol. 29, p. 405) that iron introduced as metal, or as chloride, into the electric arc, in a lime crucible, in the way which had proved successful in the case of many other metals, gave us no reversals. We succeeded, however, in reversing some ten of the brightest lines of iron, mostly in the blue and violet, by passing an iron wire through one of the carbons, so as to keep up a constant supply of iron in the arc. Considering the great number of iron lines, and that so many of them are strongly represented amongst the Fraunhofer lines, it seemed somewhat surprising that it should be difficult to obtain a reversing layer of iron vapour in the arc inclosed as we use it in an intensely heated crucible. A like remark might be made respecting titanium, which is almost as well represented as iron in the Fraunhofer lines, but has heretofore given us no reversals. Almost the same might be said of chromium, except that the number of chromium lines is so much less than that of either of the other two metals.

We have since found that most, if not all, of the strong lines of these three metals may be reversed by proper management of the atmosphere and supply of metal in the crucible. Indeed, with regard to iron we have found that the method employed with other metals was successful so far as the ultra-violet rays were concerned, though it

failed for less refrangible rays. When iron has been put into the crucible through which the arc of a Siemens' dynamo-electric machine is passing, and then fragments of magnesium dropped in from time to time, most of the strong ultra-violet lines of iron are reversed. The magnesium seems to supply a highly reducing atmosphere, and to some extent carry with it the iron vapour. It also produces a good deal of continuous spectrum, at least in certain regions, and against this the iron lines are often depicted on the photographic plates sharply reversed. In this way we have observed the reversal of the strong iron lines about the solar lines L and M, four strong lines below N, the line O, all the strong lines from S_2 to U inclusive, and two strong groups still more refrangible.

Potassium ferrocyanide introduced into the arc instead of magnesium gives a reversal of the same lines as are mentioned in the foregoing paragraph.

Iron wire fed in through a perforated pole gives reversals of the highest group (wave-length 2492 to 2480), but with the lines so much expanded as to form broad absorption-bands instead of lines.

With a vertical arrangement of the carbons, similar to that used by us for resolving the fine double lines ("Proc. Roy. Soc.," vol. 32, p. 231), and a stout iron wire in the axis of the lower (positive) carbon, many more lines in the visible part of the spectrum are seen expanded and reversed. This effect is sometimes enhanced by leading into the crucible through the upper carbon, which is perforated for the purpose, a very gentle stream of hydrogen gas; the stream must be no more than is just sufficient to give a tiny flame at the mouth of the crucible; a stronger stream diminishes the amount of metallic vapour, probably by its cooling action, and lessens the effect. By this treatment, some of the strongest lines of iron remain reversed for some time, the weaker lines are seen to expand and be reversed for a few seconds at a time, when, from a change in the intensity of the current, or some other reason, a larger amount of metal is volatilized and shows itself by burning in brilliant scintillations at the mouth of the crucible.

A list of the iron lines reversed, designated by their approximate wave-lengths, is subjoined.

5614·5
5585·5
5445·6
5428·5
5405
5396
5370·5
5327 the more refrangible of this pair.
5268·5 E

5226 the less refrangible of this double line.
5166·8 b_4
5064
5072
4956·5 both lines of pair, the less refrangible strongly.

4919·7	3727 M	3007·5	2744·7
4918	3722	3006·5	2743
4890·5	3720	3000	2741·3
4890	3707·5	2999	2736·2
4871 both lines of pair.	3705·5	2994 *t*	2722·7
4414·5	3647	2984	2720
4404	3631	2982	2718
4382·5	3502	2974	2549·5
4325	3492	2971	2545·5
4314·5	3475	2967·5	2541
4307 G	3465·5	2965·5	2535·7
4271 both lines of pair.	3440 O	2957	2534
4071	3402·5	2953·5	2529
4063	3272*	2948 U	2528·6
4045	3246*	2941	2527·3
3898	3099·5 S_2	2937	2524·2
3886	3082	2932	2523
3859	3072	2929	2518·3
3856	3057	2912	2511
3833·5	3056	2871	2502
3827·5	3046·5 *s*	2866·3	2492
3825	3041	2860·8	2491·6
3824	3036·5	2836·4	2491
3820 L	3030	2829·8	2489·3
3815	3024·5	2824·2	2485·4
3767	3022·5	2767·3	2484·6
3763·5	3020 T	2755·2	2481
3757·5	3017·5	2754·3	2480
3745·5	3016·5	2749	2474
3736·5	3008·5	2748	2465
3734·5			

It is by no means always the strongest lines which are reversed. For instance, in the group of lines between wave-lengths 5428·5 and 5396 there are four strong lines 5423·5, 5414·6, 5403, and 5382·4, which are all much expanded and diffuse when iron is introduced into the arc, but have not been seen reversed by us, while three other lines —5396, 5405, and 5428·5—are well reversed, but not much expanded.

* It is possible that these may have been the copper lines which were reversed, and not the iron lines, which are nearly identical in position.

Considering the enormous complexity of the iron spectrum, which probably reaches to something like a thousand distinct vibrations, we should expect to find a greater variation in the relative strength and reversibility of the lines of this metal, according to the circumstances in which it is placed, than we find in the case of metals giving simpler spectra. So that we may say, on the whole, that the phenomena in the case of iron are of much the same general character as we have observed before in the case of other metals; but the number of observations to be made on so extensive a subject renders it extremely difficult to come to any general conclusions.

When the perforation of the lower carbon is filled with titanium cyanide instead of the iron wire, the titanium lines come out very brilliantly and steadily, and many of them, especially in the green and blue parts of the spectrum, are expanded and reversed. We give a list of those we have observed to be reversed.

6260	5038	4535·5	4617
6257 both lines of pair.	5036	4535	4305
5223	5035	4533·2	4299·5
5209	5013	4531·7	4299
5192	5007	4690·5	4298
5129	4999	4681	4295
5064	4990	4666·5	4290·7
5039	4981	4655·5	

In the case of chromium, introduced into the crucible either as oxide or as bichromate of ammonia, there were no reversals until a gentle current of hydrogen or of coal gas was led in through the perforated carbon. This brought out the triplet in the green, wave-lengths 5207, 5205, 5203, sharply and steadily reversed, and likewise the three strong lines in the indigo, wave-lengths 4289, 4274, 4253; also a triplet near N at wave-lengths about 3578, 3593, 3606, apparently coincident with strong lines in Cornu's map of that part of the solar spectrum, and a rather strong double line just below O at about wave-length 3446. The reversal of another chromium line at about wave-length 3217 is doubtful. A triplet at wave-lengths 2799·8, 2797, 2794, is more easily reversed than any other of the chromium lines. This triplet is generally strongly developed whenever a compound of chromium is introduced into the crucible, so that we conclude that it is due to that metal, but it is sometimes visible in the photographs when other chromium lines are not seen. A still more refrangible chromium line, wave-length about 2779·6, is also frequently reversed by a gentle current of hydrogen.

The two aluminium lines near S are frequently reversed when a fragment of the metal is dropped into the crucible, the less refrangible line, wave-length 3091·5, being more strongly reversed, and continuing reversed for a longer time than that at wave-length 3080·5.